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Enhancing Retention of False Memories through Negative Emotional Arousal during Reconsolidation.

(Aumento de Retenção das Memórias Falsas através de Estimulação Emocional Negativa durante Reconsolidação.)

Agata Peliksza

Dissertação de Mestrado

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Abstract

Finn and Roediger and collaborators (2011, 2012) found that emotionally arousing negative pictures presented to subjects in the period immediately following a retrieval of a veracious memory enhances subsequent cued-recall test performance in comparison to non-arousing neutral pictures or blank screen had been shown. This finding suggests that the period just after retrieval, called reconsolidation, together with negative emotion influence, plays a significant role in enhancing memory performance. In the present study, we investigated whether such effect would be valid for the phenomenon of false memories. Participants studied lists of associated words (DRM lists). On a subsequent free-recall test, participants' generation of non-presented critical items (false memories) was immediately followed by pictures inducing a negative or neutral emotion or by a blank screen. Although we did not observed the expected significant memory enhancement for false memories followed by arousing images the results revealed less decline of memory retention (less forgetting effect) for those items compared to other retrieved words followed by neutral pictures or blanks. The results and their possible theoretical implications are further analyzed and discussed.

Keywords: false memories, DRM paradigm, negative emotion and memory, reconsolidation.

Resumo

A presente dissertação visa examinar a hipótese de que a retenção de falsas memorias - ou seja a retenção de experiências mentais consideradas erradamente como representações verídicas de um acontecimento do passado (Johnson, 1998) - é susceptível de melhoria por meio da manipulação de emoções negativas no período de reconsolidação após recuperação. O objectivo do estudo é assim investigar se emoções negativas podem facilitar o processo de recuperação e aumentar a retenção das memórias falsas quando estas ocorrem. O presente estudo pode ser visto como uma tentativa de continuação e extensão dos estudos precursores de Finn and Roediger (2011, 2012) que exploraram o efeito acima mencionado para as memórias verídicas.

Com o intuito de contextualizar o objectivo de estudo deste trabalho, começa-se por explicar em que consiste o fenómeno de falsas memórias e apresenta-se um panorama dos estudos pioneiros nesta área. Em seguida, explica-se o paradigma DRM (acrónimo de Deese-Roediger-McDermott) que usa listas de palavras semanticamente associadas e é actualmente um dos principais procedimentos de evocação de falsas memórias em condições laboratoriais. Seguidamente, descreve-se de forma breve as teorias e os mecanismos causais que fundamentam e esclarecem a ocorrência de falsas memórias. A primeira teoria, de activação-monitorização, aborda a estimulação de representações conceptuais preexistentes na memória semântica quando um item é processado dentro do mesmo domínio conceptual. Enquanto a activação converge para itens semanticamente relacionados e pode levar à recuperação de uma informação errada, a monitorização refere-se aos processos de correção e tomada de decisão que possibilitam a identificação da fonte da informação falsamente recordada (Gallo, 2010). A teoria do traço difuso faz por seu lado a distinção entre traços perceptuais (*verbatim*) e conceptuais (*gist*) de uma experiência subjectiva de codificação de informação. De acordo com esta teoria, a ocorrência de falsas memórias baseia-se na recuperação de traços *gist* (no

paradigma DRM corresponde à extração temática do significado das palavras da lista). A recuperação é causada pela interrelação semântica entre os itens.

A investigação em neurociências tem revelado, ao nível neuronal, fortes relações entre o funcionamento de zonas cerebrais particulares e a ocorrência de falsas memórias no paradigma DRM. Nos estudos que utilizaram a técnica de ressonância magnética funcional (fMRI) descobriram-se bases neurais diferentes de processos de activação e monitorização das falsas memórias. Esta investigação fundamentou os resultados obtidos nos estudos cognitivos, proporcionando e aprofundando ideias relativas aos processos de codificação, recuperação e de tomada de decisão nas falsas memórias. Em seguida, reflecte-se sobre a importância da prática de recordação na facilitação de recuperação de memórias. Esboça-se o efeito de melhoria de memorização baseada sobretudo na variante activa de recuperação, explica-se o conceito do efeito de teste *(testing effect)* e os processos que ocorrem na recordação livre dos itens. Contudo, o presente estudo concentra-se no período que segue a recuperação. Finalmente, o fenómeno de reconsolidação (onde uma informação recuperada da memória de longo prazo entra num estado breve e instável e é susceptível a modificações) é considerado como uma parte relevante e integral dos processos de retenção de memória. São analisadas correlações entre excitação, stress e emoção, e desempenho mnésico através das quais se mostra que a indução de excitação, causada pelas emoções negativas, pode melhorar a memória. Papel particular parecem ter as hormonas de stress que activam a amígdala – zona do cérebro responsável pelo conteúdo emocional das memórias. A activação da amígdala modula processos mnésicos no hipocampo, onde ocorre a consolidação das informações da memória de curto para memória de longo prazo. Em seguida, apresenta-se os primeiros estudos que mostraram melhoria da memória através de excitação causada pelas emoções negativas na fase de reconsolidação da informação (Coccoz et al., 2011; Finn & Roediger, 2011, 2012).

O presente estudo é depois introduzido como uma tentativa de verificar se também as falsas memórias são susceptíveis de sofrer o mesmo efeito de melhoria da memória. A primeira tarefa do estudo é baseada no paradigma DRM clássico para gerar memórias falsas. Com este propósito usam-se listas DRM portuguesas (Albuquerque, 2005). Numa primeira tarefa de recordação livre, cada vez que uma palavra crítica foi recuperada, uma imagem de carga emocional negativa ou neutra foi apresentada imediatamente depois. Um teste final de recordação livre de todas as palavras das listas é utilizado para verificar se falsas memórias, obtidas na primeira tarefa e seguidas de imagens negativas (condição facilitadora), eram melhor recordadas em comparação com as seguidas por imagens neutras.Com base nos estudos anteriores, que mostraram melhor desempenho mnésico quando a recuperação de uma memoria verídica é acompanhada por um acontecimento negativo (em comparação com um positivo ou neutro), espera-se obter um efeito de reconsolidação também para itens críticos (falsas memórias).

Na análise dos resultados o foco centra-se no efeito de retenção das palavras críticas e verídicas nas duas condições principais do estudo – de tarefa (recuperação inicial e final) e de imagem (recuperação em função de valência de imagem). Por conseguinte, examina-se a interação entre estas duas variáveis. Ao examinar os resultados de memórias falsas o segundo item crítico (IC2) tornou-se impossível de analisar. Ocorreram somente quatro únicos casos de recuperação deste item na tarefa inicial e nenhum na tarefa final. Consequentemente, ficou excluído da análise. Os dados da análise estatística (ANOVA) revelam o efeito principal significativo para condição de recuperação, indicando uma melhor recordação das memórias falsas na tarefa inicial do que na tarefa final. Estes dados estão de acordo com a curva de esquecimento que demonstra a queda de retenção da memória com a passagem de tempo. O efeito principal de imagem é marginal, o que indica uma incongruência inexplicável entre a taxa de falsas memórias seguidas de imagem negativa ou neutra. Contudo, a análise de

resultados revelou, em linha com o esperado, uma maior queda de memórias falsas seguidas de imagens neutras do que negativas. Todavia, um teste adicional, onde se controla a discrepância inicial entre a proporção de memórias falsas seguidas de imagens neutras ou negativas, mostra que a condição de imagem não tem o efeito de consolidação esperado.

A análise de resultados das memórias verídicas foi consideravelmente limitada por causa do pequeno número de *targets* obtido, devido ao uso do paradigma *oddball* (ver Finn e Roediger, 2011*)*. Agregando os dados por sujeito e por item, de forma a aumentar o número de respostas, não se obtiveram diferenças significativas na recuperação entre memórias verídicas nas três condições de imagem (negativa, neutra e ecrã em branco). Deste modo, os resultados do presente estudo não replicam os obtidos por Finn e Roediger (2011, 2012).

Por fim discutem-se os presentes resultados, as limitações assim como sugestões para as ultrapassar em estudos futuros.

Palavras chave: falsas memórias, paradigma DRM, emoção negativa e memória, reconsolidação.

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Introduction

Memory refers to the processes that are used to acquire, store, retain and later retrieve information. Regardless of the specific representations proposed by different memory models, it is usually accepted that every new-learned item is stored as a memory trace in the brain. However, such a trace is very prone to fade unless it is traced again by a related experience, revision, repetition or retrieval.

Research on memory retrieval has demonstrated that this process is not neutral. Every retrieval episode changes the actual state of memory and has a great effect on remembering. It produces better retention than restudying the same material, given equal amount of time. This is termed a *testing effect*. Theoretical explanations on how retrieval practice affects memory (*testing effect*) aroused a lot of interest recently (Roediger & Butler, 2010). This effect is particularly surprising as it appears even when people do not receive feedback about their test performance (Karpicke & Roediger, 2007), and even when attempts of retrieval are unsuccessful. Therefore, either successful or not, retrieval supports and increases the probability that an attempt would be successful later on.

Retrieval itself is a powerful tool for memory enhancement, however, recently, a few studies revealed the importance of postretrieval processing in strengthening the standard *testing effect*. This period that follows immediately after retrieval seems to offer an opportunity for *reconsolidation*. Right after an information is retrieved from memory it passes into a labile state during which it seems to be amenable to change, in strength or in content. Upon *reconsolidation* a memory trace may be modified - distorted, impaired or strengthened (Nader, 2010). This stabilization of memory occurring after retrieval is responsible not only for better storage, but also for the plasticity of old memories. The functional role of *reconsolidation* is most probably to strengthen a reactivated memory trace and augmenting its long-term retention. Also, it is thought to enable memory to be updated with new information (Coccoz et al., 2011). This information, introduced during reactivation of an old trace, triggers a new encoding state, where memory can be manipulated. Thus, every *reconsolidation* episode may change an existent mnemonic trace. However, the *reconsolidation* account does not determine the direction of influence on memory. Basically, it focuses on the process of reopening old memories for eventual change. Only the subsequent post-reminder manipulation attempt conducts and shapes this influence.

Research exploring these post-reminder manipulations has shown that emotional stimuli can have an impact on retention and later retrieval, namely, it may enhance it. Emotions generally facilitate memorizing. Events that cause emotional arousal are usually better remembered than neutral ones (emotional enhancement of memory, EEM). The modulation hypothesis of the EEM suggests that the amygdala, active during emotional situations, strengthens hippocampal consolidation of memory traces for emotional events (Sommer et al., 2008). This activation of the amygdala happens via stress hormones release. Adrenaline and cortisol, secreted during emotional arousal, enhance long-term retention after learning episode or training experience (McGaugh, 2006). The stress hormones release is also highly related to the act of retrieval. It has been shown that noradrenergic stimulation is an efficient way to facilitate recall (Sara, 2009).

The effect of better retrieval for emotional events was found to be more pronounced for negative and highly arousing images or words (Ochsner, 2000). Neuroimaging research indicates that some processes involved in retrieval of positive and negative experiences differ (Kensinger, 2009). In particular, interactions between emotional arousal and sensory processing may be stronger upon retrieval of negative than positive experiences.

Recently, Finn and Roediger (2011, 2012) conducted two innovative studies on emotional arousal and reconsolidation. Their experiments demonstrated for the first time memory facilitation resulting from post-retrieval negative emotion manipulations. Their results revealed a better retrieval (on a second retrieval task) of items (retrieved in a first retrieval task and) followed by negative pictures in comparison to neutral pictures or blank screens. The enhancement effect was also observed for unsuccessful, but active and effortful retrieval attempt. Generally, these pioneer studies provided evidence that post-retrieval reconsolidation via negative emotion processing may strengthen the well-known testing-effect.

The present work follows the footsteps of Finn and Roediger´s (2011, 1012) findings and aims to extend them onto the phenomenon of false memories. The main interest of this experiment then is to verify whether false memories are also prone to this kind of emotional reconsolidation.

False memories are mental experiences that are mistakenly taken to be a veridical representation of an event from one's personal past (Johnson, 1998). The most popular method to study false memories is based on Deese (1959), Roediger and McDermott (1995) paradigm (McDermott & Chan, 2010). Within this paradigm, subjects are presented with semantic associates of some critical word that is never really studied but is very frequently mistaken and taken for a studied word on the test. These non-presented critical items commonly have very much alike characteristics as studied ones - they are often described as *old* on recognition tests, spontaneously generated at recall tasks and their encoding is frequently remembered with vivid detail.

In the research here reported it was examined whether an emotionally arousing event, more precisely, a negatively valenced picture, which appears soon after retrieval of a critical, non-presented word, may enhance its retention and thus consolidating a false recall. Given the prior work of Finn and Roediger (2011, 2012) there is evidence that negative emotion enhancement effect occurred at retrieval of veridical memories. This time, the DRM paradigm is used to elicit false memories that are subsequently, followed by negatively valenced pictures, neutral pictures or blank screens.

The introductory part of the present work provides a background for the false memories phenomenon, explaining the paradigm that triggers their appearance and pointing out the theories and causal mechanisms underlying the emergence of false memories. Then, the importance of retrieval practice in recall facilitation is described. Subsequently, some attention is paid to the role of reconsolidation and emotion. At last, former studies of memory strengthening effect through post-retrieval manipulations will be briefly reviewed and an overview of the present study is presented.

Early research on false memories

The idea of associationism is thought to be dominant in explaining human phenomenon of learning and memory. This trend has its beginning in ancient times when Aristotle started to deliberate on the memory mechanisms and it led him to hypothesize a few laws of association: similarity, frequency or contrast between elements among others. He claimed that "acts of recollection, as they occur in experience, are due to the fact that one movement [that is, one thought] has by nature another that succeeds it in regular order."[1] Nevertheless, only in the sixteenth century in Great Britain the concept of associationism started to form and develop. The first empirical study concerning human memory (conducted by Ebbinghaus, 1885/1999) demonstrated either direct or remote character of associative connections. Meanwhile, other British researcher (Mary Calkins, 1896/2006) created and introduced the paired-associates learning technique to investigate the process of generation

[1] Aristotle, De memoria et reminiscentia, [in:] "Theories of Memory. Volume II", M.A. Conway, S.E. Gathercole & C. Cornoldi, 1998, p. 187

and remembering of associations in a more direct way. Even with the start of cognitive revolution in 1950s associative theories with their strong evidence could not be discredited. Memory models appearing at this time were set on earlier premises of its associative character.

Associative nature of memories is concerned as a mighty dynamism that supports processes of remembering. The stronger the associative connections between two items, the easier it is to recover one given the other. However, until recently it has been hardly ever pondered that this associative force may be misleading. This matter seemed to be forgotten and received almost no attention among researchers. Nowadays it is known that these dynamic and robust associations also have their drawback and are a source of memory errors and distortions.

Kirkpatrick (1894) is thought to be pioneer in pointing out this phenomenon. Although he was mainly interested in determining which kind of presentation mode (e.g., visual or auditory) was best retained, Kirkpatrick observed incidental illustrations of false recognitions. In his studies, while hearing lists of ten common words such as "spool", “thimble”, “knife”, many participants thought at once of the associates “thread”, “needle”, “fork”, and later often recalled them as being part of the presented word lists.

Going further into this historical overview of associative memory distortions, attention needs to be paid to the most influential experiment in the area conducted by Bartlett (1932). His participants were asked to reproduce an Indian folklore tale from a different cultural background unfamiliar to the readers. Later on, subjects were asked to recall it several times, at different points in time (e.g., immediately after reading the tale, 15 minutes later, 4 weeks later, etc.). Such repeated reproduction revealed many modifications in comparison with the original. Some parts were subtracted, others were over-elaborated, and still others were new additions. The author of the study also observed that memory reconstructions were commonly in line with participants´ cultural concepts than with the circumstances and the background described in the story.

Nevertheless, the major contribution of Bartlett (1932) to modern psychology was the proposal that remembering is not a reproductive but a reconstructive process and thus, predictably unreliable. In his belief, perception and comprehension of an event does not take place automatically, it is rather an effort after meaning. That is, an attempt to mentally represent one´s understanding of a given event. Therefore, if encoding is a construction then a trial of recollection should be considered as a reconstruction of a past experience. This effort of remembrance partly derives from memory traces of previous events, but it origins mostly from one´s mental schemas, i.e., one's general knowledge, beliefs, expectations, or suppositions about what must have happened. These schemas, as Bartlett (1932) argued, support and guide input encoding and retrieval. As such, a memory of a past event may be inaccurate and contain errors, when it is based on mental schemas that allow for the comprehension of the event and not by its factual traces. This schema-based reconstruction can be considerably exact and correct but whenever recollection fails, the schema's general knowledge fills in the information gaps providing memory for events rich in meaning.

Underwood (1965) followed the concept of Bartlett (1932) and demonstrated the associative mechanisms of memory using a learning list paradigm. Participants were asked to perform a 200-word continuous recognition test, in which streams of heard words were related in meaning. People were more likely to falsely recognize an item (e.g. needle) if they had previously been presented with associated words (e.g. thread, haystack, etc.). Underwood interpreted this observation as a proof for the existence of an associative network that triggers the generation of unstudied semantic associates of the words presented. This study led him to propose the concept of *implicit associative response* (IAR). As he suggested, the perception of a word may give rise not only to *representative response*, (the actual signification that a given word conveys) but also provoke the involuntary association - the *implicit associative response*, of which a person becomes consciously aware.

As Deese (1959) made it evident in his research a few years earlier than Underwood (1965), false memories may also be induced in the process of free recall of word lists. Initially, Deese (1959) did not target on remembering failures but aspired to explore arguments in favor of associative nature of memory. He intended to discover a method to obtain significant levels of false recollections with the purpose to find a relation between memory intrusions and list structure. In his well-acknowledged experiment he developed 36 wordlists with strong associative connections so that they could be used both to figure out correct recall and intrusions. Each list was composed by 12 items correlated to one critical non-presented word (e.g., associates: *bed, rest, awake, tired, dream, wake, night, eat, sound, slumber, snore, pillow*; critical word: *sleep*). On a free recall test he was interested in the probability with which participants would retrieve the critical non-presented word. Despite the lists were collections of the most frequent words evoked in response to the target during a free association task (so-called forward associates), the average probability with which associates triggered a "theme word" as belonging to the list, i.e. the sum of associative forces from each one of the list words to the critical one (*backward association strength*, BAS), varied from list to list. Deese (1959) predicted that variation in the associative frame (particularly in the BAS) might influence the probability of intrusions occurrence. The experiment confirmed his hypothesis; the probability of false memories was remarkably correlated with the BAS of the wordlists ($r = .87$). In this way the author of the study came to the conclusion that the associative frame of a list was fundamental to the rate of veridical and false retrieval.

DRM paradigm

Despite of Deese´s (1959) striking conclusions the psychological sciences community did not pay much attention to his work until the middle nineties. Then, Roediger and McDermott (1995) started a research program based on Deese´s (1959) finidngs, improving and expanding them. They replicated the results of false recall and introduced the recognition test.

Roediger and McDermott (1995) performed two experiments. In the first one they employed 6 lists with the 12 strongest semantic associates of a non-presented critical item. The lists were picked from Deese´s study, according to the highest degree of intrusions they produced. First, participants proceeded with hearing and then with recalling the lists. Subsequently, they were given a recognition task that included presented and non-presented words, together with critical ones. Obtained results corroborated Deese´s (1959) conclusions and revealed high levels of false memories during recollection. The non-presented "critical items" were retrieved with about the same probability (40%) of the items from the middle of the lists. On the recognition test, subjects showed a tendency to declare non-presented words as old with almost equal rate as those that in fact had appeared on the lists. The number of students who were confident about the non-presented critical item occurrence exceeded fifty percent. Besides the replicating the first experiment's results, the goals of the second experiment, include investigating the effect of previous recall on the following recognition task, verifying the false alarms rate for critical-items of non-presented lists and, as the authors considered most relevant, exploring participants' phenomenological experience in the recognition test. To examine such experience Roediger and McDermott used Tulving´s (1985) *remember-know* procedure, according to which human retrieval is a combination of *remembering* and *knowing*. *Remembering* refers to a conscious retrieval of prominent contextual elements, when a person is able to mentally re-experience an event. *Know* in turn, is a common sensation of familiarity without recollection and capacity to relive what happened. An individual, while assessing an event as a *remembered* or *known,* uses episodic and semantic memory, respectively. In this experiment subjects were asked to study a set of 24 lists, each with the 15 strongest associates to a non-presented word. In the first phase participants carried out an immediate free recall test and subsequently performed a recognition task with *remember-know* judgments. These second experiment with longer lists brought an increase in false recall to 55%. Remarkably, most false alarms were reported as *remembered*.

Roediger and McDermott (1995) dubbed this method, first used by Deese (1959) the DRM paradigm (an acronym for Deese-Roediger-McDermott). The simplicity of the experimental design and robustness of obtained effects made it to be an extremely popular paradigm in memory research. The DRM provides a great degree of experimental control in false memory studies in various domains like neuroimaging, neuropsychology, development, aging or individual differences.

Typically subjects are presented, in oral or written form, with a set of semantically related words which all converge on a non-presented critical item. After that, they are asked to recall and/or recognize as many words from the lists as possible. The recognition list is composed of words previously presented, unrelated new words and critical-words (one for each list).

Results, brought about by DRM studies, emphasized the point that memory mostly consists in constructive processes. The new and outstanding conclusion, that the paradigm provided, was that even a simple trial of remembering of a word stream may be based on constructive processes. According to Roediger and McDermott (1995), false memory illusions demonstrated that yet, the most elementary tasks, like memorization, require not only reproductive but constructive mechanisms too.

This section is a thumbnail description of DRM paradigm. Created on the basis of lists of strong semantic associates, it is nowadays a leading technique in evoking false memories in lab conditions. In our study, as we aim to investigate the effect of some manipulations on false memories, the use of DRM paradigm seems to be an effective method to obtain them. Several studies using this paradigm have shown that rates of recall and/or recognition for the non-presented theme-word occur at high rates that are frequently close to those of recall or recognition for the presented listwords.

Several theories have tried to account for the DRM results. And although there have been some divisions in the camp, there are two dominant accounts that will be reviewed further, *activation-monitoring* framework and *fuzzy-trace* theory.

Theories of false memories

Activation-monitoring theory

According to the activation-monitoring framework, *activation* stands for mechanisms that intrinsically trigger the related item or afford retrieval of some possible erroneous information. *Monitoring* refers to correction and decision processes that allow identifying the source of such false information (Gallo, 2010). These two modes act antagonistically, when *activation* boosts memory illusions, *monitoring* tends to diminish them.

The *associative-activation* concept is dominant in this matter. It consists in stimulating preexisting conceptual representations from semantic memory when another item is processed in the same conceptual domain. Present-day approaches to associative framework of false memories refer to Underwood´s (1965) *implicit associative response* (IAR) hypothesis. He suggested that when a word is studied during encoding, an individual might intrinsically trigger a corresponding word. For instance, when he sees the word "black" may think about the associate "white". Subsequently, at retrieval, a person may recall or recognize such an associate due to its former activation at encoding, either implicit or explicit, no matter if the associated word ever occurred or not. Underwood (1965) also noticed that the more words raise implicit responses around the same critical item, the more probable it is for this item to be recognized later.

Other, more up-to-date accounts of activation have further modified Underwood´s (1965) hypothesis, relying on more modern cognitive evidence. Their basic assumption is that individuals have their own word stock, developed during a lifetime. Nodes symbolize concrete words and ideas. Moreover, this internal vocabulary is systematized in semantic maps, in which *nodes* with corresponding meaning have strong links. The semantic interrelation is a principal postulate of the approach, however, aspects like common word-pairing, contribute to the strength of the associative matches as well. The crucial assumption of this framework is built on Collins and Loftus (1975) *spreading-activation model* of semantic processing. It says that processing of one item, for instance "thread", stimulates the corresponding *node* in mental lexicon. This stimulation expands and reaches neighboring *nodes* and elicits associated words such as "needle". Investigators claim that this spreading activation runs fast, occurs rather automatically and vanishes quickly. Priming is a method that can provoke this activation. Various studies demonstrate that prior, brief presentation of a prime word or concept may evoke that memory and make it easier to access. For instance, it was found that people could more easily give a name to an item within a category if it was the second one they were asked to provide in the recall task. Further, Ratcliff and McKoon (1981) proved that priming target words with closely associated ones resulted in shorter reaction times than priming it with words distant in meaning. Certainly, activation does not seem to be enough to explain the phenomenon of false memories in the DRM paradigm, taking into consideration that they can appear even months after the experiment. Still, the associative-activation theory puts forward at least two arguments to come out for the persistence of false recall and false recognition. One argument regards the activation of the critical word at studying, and it is believed to produce enduring memories. During the encoding phase people learn various words that combine together, so that the lure becomes triggered many times and this activation adds (Gallo, 2006). Roediger and collaborators (2001) stated that false recall seems to be determined by the aforementioned *backward association strength*. When the added activation in this process comes to be strong enough, the critical word may enter one´s conscious awareness and be encoded as an episode that really took place. Such a memory, when iterated falsely as a veridical, may remain for a long time and later be wrongly defined as one that appeared on the lists (Gallo, 2006).

The other argument concerns the test phase. Here, it is considered that subjects could think about the critical word at recall or recognition tasks, when either they are presented with or retrieve from memory studied associated items. If the activation of the critical word at recall or recognition test creates in subjects a feeling of familiarity, then it could be deduced as being formerly presented during study phase.

The idea of monitoring addresses mainly two mechanisms proposed by the source-monitoring framework (Johnson et al., 1993). They are both recollection-based, i.e. they both stem from the concept that reinforcing veridical recollection is able to reduce false memories. Tulving (1983), based on the results of his "direct comparison" experiment, suggested that monitoring in memory relies on a *reject-to-recall* process. The phenomenon reveals that if a recognition lure awakens memories of its related studied items, then a person can think and choose not to label the retrieval cue (i.e., the lure) as "old" even if it seems familiar. Gallo (2004) further divided this recollection-based monitoring in *disqualifying* and *diagnostic* monitoring, regarding the decision process one takes. In both of them an individual uses recalled data to verify and edit the accuracy of retrieved memories. In the case of *disqualifying* monitoring one discredits a doubtful event, when comparing to an earlier experienced one, it brings incoherent recollection. Hence, a *disqualifying* method is a rulebased one and depends on the knowledge of a given situation - the encoding context. On the contrary, *diagnostic* monitoring is heuristic based. It consists of making a memory decision grounding on expectations. If an item does not evoke the expected recollection, it is considered “new” (i.e. not previously presented). *Diagnostic* monitoring aids the rejection of non-presented items because the remembered information helps in creating expectations about what a person should recall from formerly experienced events. This kind of *recall-to-reject* is considered to be dominant due to the fact that the spotlight here is directed on the quality of memories for the questionable occurrence. *Disqualifying* strategy is somehow auxiliary, being derived from secondary data, which leads a person to judge whether something has really happened, or not.

The importance of expectations in *diagnostic* processes was emphasized by Schachter and collaborators (1999). They discovered that some manipulations in the form of presentation of studied material influenced and increased recognition, whether an item had actually occurred or not. They found out that presenting DRM lists in which each word was paired with a picture substantially decreased false memories in comparison with the classical, words-only presentation format. This is thought to happen because of subjects expectations that studied words would make them recall of the associated pictures. Since the critical words do not have no picture associated they become distinctive and are more easily diagnosed has not previously presented. Hence, a lack of picture retrieval for a test item becomes diagnostic for the decision that the given item had not occurred. One more argument in favor of the hypothesis that distinctiveness augments the capacity of monitoring was provided by Roediger, Balota and Robinson (2000). In their study they demonstrated that if items were presented during longer time, subjects were more able to perceive and then to retrieve them at recall and recognition tasks.

With the help of *disqualifying* monitoring (Gallo, 2010), some other effects in the DRM tasks could be explained. When subjects in the beginning of the study are warned to avoid creating false memories it actually diminishes the scale of the illusion. It is considered that alerting participants of possible occurrence of false memories make them paying more attention to identify the critical word and label it in memory as a non-studied one. Afterward, at recall task, such information helps in disqualifying that word as had been presented. What is more, this kind of monitoring may happen even when participants do not receive a special forewarning (Carneiro et al., 2009). In other research (Gallo, 2006) it was proved that if a critical item is included in a formerly presented "to-be-excluded" list, there is a greater possibility that participants would avoid it on a later test. Gallo (2004) suggested also that the "theme" word is not recognized so often when subjects can exhaustively remind all of the studied items from a list. In all of three examples mentioned above the critical word may be eliminated due to effective recall of a piece of disqualifying data.

Fuzzy-trace theory

The other account for the DRM results is proposed by *fuzzy-trace* theory (FTT). It is based on a few postulates that are able to explain the phenomenon of DRM illusions (Brainerd & Reyna, 2002). All of these postulates engage the distinction between *verbatim* and *gist* traces of subjective encoding experience. The *verbatim* stands for the superficial, perceptual form of the episodic experience and embraces contextual cues. Regarding DRM lists, it involves specific details of items, e.g. their list position. *Gist* traces contain meaning, these are concepts retrieved as the aftermath of the analysis of encoded perceived forms. In DRM paradigm, *gist* formation results from the thematic extraction of the list meaning. The interrelation between items of the list enables to derive the core of the list. In this way, retrieved critical item is congruent with the list theme - the *gist*.

Encoding and storage of both *verbatim* and *gist* memory traces function in a parallel way. According to FTT, retrieval of *verbatim* traces is recollective, whereas of *gist* traces is non-recollective. Hence, retrieval is thought to occur through separate pathways, independent of each other. It is influenced by aspects such as availability of retrieval cues, easiness of access and forgetting of both kinds of traces. Regarding retrieval cues, items and events that were in fact experienced, serve as better retrieval cues in case of *verbatim* memories, while items that have not been perceived but preserve the meaning of experience, are better cues for *gist* traces. Forgetting concerns the fact that perceived superficial features of items vanish faster than memory for meaning, therefore, one has longer access to *gist* than to *verbatim* traces of an experience. FTT presumes the activity of opponent processes in false memories. *Gist* retrieval is believed to foster them because of the seemingly overlap of meaning, on the other hand, *verbatim* retrieval counterbalances this tendency, since critical items do not possess verbatim traces, which help hindering memory illusions. Another important principle that can be found in FTT is that both kind of retrieval provoke vivid remembering. Verbatim retrieval fosters it and when it occurs, a person is able to consciously re-experience an event in mind. *Gist* traces bring more general retrieval - similar to a sense of familiarity, where participants have a notion that an item has already appeared but is unable to explicitly recall it.

Fuzzy trace account explains the way of occurrence of false memories relying on the retrieval of *gist* memories. There are some specific factors, which may promote their arousal. For instance, semantic relatedness of given cues will rise the retrieval of *gist* memories.

Results of McDermott (1996) and Payne et al. (1996) studies showed that false memories persisted over a delay for both recall and recognition tasks. According to FTT, this is because the verbatim-based memories that hold up veridical recollections, are quickly and more easily forgotten than the gist memories that are the base for false recollections. Brainerd and collaborators (1995) investigated this presumption with the use of wordlists. Their observation was that false recognition of semantically connected misleading clues was more persistent after a delay than right recognition of presented words. This result is in opposition with the source-monitoring theory, where it is claimed that false memories for non-presented items are supposed to be forgotten over time in the same way as the other list items. Therefore, FTT assumes the stability and persistence of false memories over time. After a sufficient delay, gist memories come to have a dominant function in memory, while verbatim pass to be inaccessible.

This description of main explanatory theories regarding false memories was made to provide an insight and better understanding of processes that underlie the phenomenon of false memories production. Comprehension of false memories depends upon reflecting on two, aforementioned, mutually exclusive mechanisms – an error-inflating and an error-editing mechanism. In the activation-monitoring framework these error-inflating processes are called *activation*, when in fuzzy-trace theory it is defined as *gist encoding*. Regarding error-editing processes, they correspond to two decision processes - *diagnostic* and *disqualifying* monitoring in activation-monitoring theory; and the retrieval of true verbatim traces or memory for specific information in fuzzy-trace theory.

Neural bases of false memories

In recent times, false memories became a subject of interest of neuroscientific studies. Neuroimaging techniques as EEG (electroencephalography), PET (positron emission tomography), fMRI (functional magnetic resonance imaging) or ERPs (event-related potentials) are sometimes capable to distinguish true from false memories in laboratory conditions. Many of those studies have designed experiments in which participants at the beginning learn lists of semantic associates or perceptually similar visual shapes. Then, researchers carry out scanning the brain activity of subjects as they attempt to recognize as old or new three different types of items: old items that occurred earlier in the list, semantically or perceptually related new items that did not appear before or unrelated new items that did not appear before. In these experiments, participants normally classify the old items as old much more often than they classify the new, unrelated items as old, what stands for an evidence for veridical memory. However, the essential result is that participants also categorize new but unrelated items as old much more frequently than new and unrelated items. These incorrect answers to the related items are false memories (Slotnick & Schacter, 2004). Other neuroimaging studies have examined false memories that derive from confusing perception and imagination (Kensinger & Schacter, 2006). For instance, after seeing images of some objects (e.g., a photo of a car) and imagining others as a response to a verbal cue (e.g., “imagine a glass”), it happened that participants sometimes falsely remember that they saw a photo of an item they have only imagined (a glass).

The aforementioned studies have typically shown that many of the same brain regions become active for veridical (“old” answers to old items) and false memories (“old” answers to related, imagined or suggested items), but there have been also some differences found. For instance, several studies have documented that brain areas engaged in encoding or retrieval of sensory-perceptual data tend to be more active for retrieval of veridical than retrieval of false items (Slotnick & Schacter, 2004; Kensinger & Schacter, 2006). Although the exact regions that distinguish veridical from false memories vary in different researches, the results are usually in line with the sensory reactivation assumption that came out from previous behavioral studies, showing that true memories are likely to be associated with retrieval of greater sensory and perceptual features than false memories.

There is also an evidence that specific brain areas like anterior prefrontal cortex, especially in the right hemisphere, is preferentially triggered for false in comparison to true memories, eventually signaling a role for anterior prefrontal cortex in memory monitoring or decision making (Slotnick & Schacter, 2004).

In what regards the DRM illusion investigators have discovered different neural underpinnings of activation and monitoring processes. fMRI studies of meaning extraction from language (Hasson, Nusbaum & Small, 2007) documented that left inferior prefrontal and lateral temporal areas are active when participants process the semantic associations in DRM lists (McDermott, Watson & Ojemann, 2005). These brain regions supposedly play a role in the activation of the related critical item.

Evidence points as well to the medial temporal lobes (MTL) as being involved in the processes underlying the DRM tasks. Damage in these regions is associated with autobiographical amnesia and impairs true and false memories in the DRM tasks (Van Damme & d´Ydewalle, 2009). Analogous results have been found in patients with Alzheimer´s disease, where MTL areas are also affected (Budson et al., 2001).

Research in which neuroimaging technique was used has also implicated MTL regions in the DRM false memories. Equivalent fMRI activity was found in the hippocampus when remembering studied items or falsely recognizing related critical words as compared to unrelated ones. This activity can be translated in the retrieval of associations or gist that could provoke activation of the related critical item, however, it may reflect at the same time the retrieval of real memories in an attempt to monitor. In this case, when both activation and monitoring processes contribute to DRM illusion, neural activity associated to critical items may be unclear.

In comparison with the PFC and MTL areas that have been matched to activation, other PFC regions have been reported as playing role in monitoring. Patients with some injuries in dorsolateral PFC were more prone to the DRM illusion that subjects from control group, with only small differences in true recognition (Budson et al., 2002). These results presume that some kinds of PFC damage may impair monitoring skills, whereas others may have a more amnesic implications. Neuroimaging researches point out as well that the dorsolateral PFC is crucial for retrieval monitoring. Greater fMRI activity is typically found in the dorsolateral PFC for studied items and related critical words, when compared to unrelated critical words (Cabeza et al., 2001). Moreover, the dorsolateral PFC has been implicated in tasks that, unlike DRM, were precisely meant to isolate retrieval monitoring processes (Gallo, McDonough & Scimeca, 2010).

The idea that PFC supports monitoring processes at retrieval is hold by increases in the DRM illusions related with aging, which is in agreement with the notion that PFC function declines in older adults (Balota et al., 1999). Aging-related growth in false memories is the main condition that places a high demand on monitoring at retrieval or in older adults who have their frontal functioning reduced. As the PFC region is known to have a late development, it stands for an evidence for reduced retrieval monitoring in children too (Carneiro & Fernandez, 2010). Nevertheless, in contrast with adults, children show reduced relatedness effects in the DRM tasks, which possibly reflects undeveloped semantic networks or gist-based processing (Brainerd, Reyna & Forrest, 2002). These developmental models bring further evidence for the complex interaction between activation and monitoring processes in the DRM tasks resolving.

This section reviewed neuroimaging findings particularly from functional magnetic resonance imaging studies. Such research grounds the results obtained in cognitive behavioral research and provide further insights regarding the encoding, retrieval and monitoring processes in false memories at neural level. It exposes the relations between functioning of particular regions of the brain and DRM illusion occurrence.

Retrieval-based long-term retention - *testing effect*

One issue of experimental cognitive psychology is worth to be considered in this work, namely, how and why retention of memories occurs and how it could be strengthened. Science has continually demonstrated that "active retrieval" is the most effective way to enhance memory. During the nineteenth century, Hermann Ebbinghaus, a German psychologist, who pioneered the experimental study of memory, made several findings in the domain of memory recall that remain relevant until today. He subjected himself to a series of tests, where he had to learn random strings of nonsense syllables and later examine their recall. Ebbinghaus discovered, among other things, that all memories gradually decline. However, this weakening decreases every time information is being reviewed. Further, a memory trace is build up at every restudy episode, especially, if these episodes are repeated several times spaced over a long time span rather than repeatedly studied in a short period. This finding is known as a *spaced repetition* or *spacing effect* and it is thought to be an effective way of long-term remembering.

In "The Principles of Psychology" (1890/2011) William James already points out "[...] A curious peculiarity of our memory is that things are impressed better by active than by passive repetition. I mean that in learning, when we almost know the piece, it pays better to wait and recollect by an effort within, than to look at the book again. If we recover the words the former way, we shall probably know them to the next time [...]".[2] James (1890/2011) called attention that retrieval practice provides greater long-term remembering than studying or restudying the same piece of information.

Tulving (1967) conducted an experiment where he examined learning of word lists and found that testing itself may cause as much learning as studying of a material. In this study participants were presented with 36-words lists in a random way at every study trial.

[2] William James, *The Principles of Psychology*, 1890, [in:] "The critical role of retrieval practice in long-term retention", H.L. Roediger & A.C. Butler, 2010, p.1

There were three experimental conditions, participants took a test under standard *study-test* (STST), *repeated study* (SSST) and *repeated test* (STTT). Every condition had 6 cycles. Further, participants were asked to perform an oral recall of the items. Unexpectedly, results revealed that the learning curves for all conditions were almost equal. Participants recalled about 20 words in each condition (18.5 words in STTT). However, in repeated-test condition, subjects studied the material only 6 times, but still they recollected almost the same number of items as those who had 18 study trials in SSST condition. All in all, more study time in repeated study circumstances did not enhanced memory performance. Even if in repeated test condition subjects retrieved hardly noticeable lower number of words in comparison with the other two cases, what is important is that the difference between the conditions diminished across test series.

Tulving´s (1967) investigation unfolded a phenomenon which is known now as a *testing effect*. *Testing effect* is defined as a retrieval of information from memory which provides better remembering than restudying the same information over the same amount of time (Roediger & Butler, 2011). Recent investigation in this domain has demonstrated strong profits of retrieval-based learning on memory. However, the results are better under certain conditions. It was showed that expanding schedule of retrieval is a method that meets these requirements. Introduced first by Landauer and Bjork (1978), the procedure consists in prolonging gradually the intervals between subsequent retrieval attempts. The idea of expanding is to increasingly shape long-term memory of a given data. The researchers proved that this constant prolonging of retrieval interval would give better results than making identical pauses between memory trials or repeated retrieval without such pauses at all (massed schedules). Other evidences show (e.g., Karpicke & Roediger, 2007) that expanding retrieval practice provides better short-term retention memory, however, equally-spaced retrieval practice promotes long-term retention by increasing the difficulty of retrieval on the first test. Furthermore, t*esting effect* enhances later retention even when people are not given a correct answer or a feedback after they have taken a test (Roediger & Karpicke, 2006). Nevertheless, when a response is provided, it improves the overall mnemonic effect (Roediger & Butler, 2010). Feedback is advantageous because it permits to correct mistakes and conserve the right answers. Moreover, both in case of successful or unsuccessful retrieval attempt, feedback makes it more probable that a trial would be successfully retrieved later. The way of giving correct answer also has its significance. Experimental studies show that delayed feedback could bring even better effects than immediate one (Roediger & Butler, 2010). Kornell and collaborators (2009) try to explain the aforementioned memory enhancing effect in case of unsuccessful retrieval providing three theoretical approaches. First, regarding *search set* theory, it means that a cue, which is showed formerly, activates seeking processes and triggers associates. The activation itself boosts the encoding of associates at retrieval, when they are presented later as target words. The second approach concerns *error correction*. It is thought to happen if any incongruity between the correct answer and one´s response occurs. Then, an error signal is generated and a general error correction process eliminates the discrepancy, favoring the target answer. Thirdly, there is an *additional cue* theory that claims that the outcome of an initially failed retrieval is recalled later at another attempt and serves as an extra cue, helping retrieve the target response. However, all three explanatory concepts mentioned above are not mutually exclusive.

Retrieval-based practice results have been extensively examined, so that nowadays, there are known more conditions that need to be satisfied in order to a *testing effect* appear. The main interest of the phenomenon lies in the explanation of how a retrieval itself affects memory. One popular approach proclaims that retrieval of some memory provokes its elaboration and/or formation of another retrieval paths which make grow the probability that this piece of information will be retrieved more easily later on (Roediger & Butler, 2010).

Another idea highlights the notion of retrieval effort, which may reflect the frequency of reprocessing of a memory trace at retrieval. Thus, the more effortful is the recovery of one memory, the more elaborated is the reprocessing. Subsequent theory holds the idea that cognitive processes involved in encoding, when they correspond to those employed in retrieval, the memory performance becomes enhanced. However, all of these three theories combine together in a recent concept of Bjork and Bjork (1992). The researchers make a distinction between storage and retrieval strength, i.e. maintenance and accessibility of a memory, respectively.

Thanks to previous research it is known now that retrieval is not only a tool for evaluating one´s knowledge, but serves as a booster in meaningful learning, i.e. robust and long-lasting remembering processes. All of them are retrieval-dependent and base on the available contextual hints. Every retrieval episode causes changes in the stored knowledge, modifying the diagnostic value (described earlier in text) of contextual cues and facilitating future memory recovery. Here, the concept of reconsolidation comes into play - the idea that retrieval of a memory trace makes it enter into a labile state and prone to be changed - enhanced or disrupted.

This section presented a sketch of retrieval-based memory enhancing effect and it emphasized that an active variant of retrieval plays here a particular role. The section shortly describes explanatory approaches of *testing effect* and provides an idea of processes that take place at free recall task the participants were submitted to. However, the main point of interest of the present study lies in the period that follows retrieval and it will be delineated in the next section.

Reconsolidation

After every act of learning a new memory undergoes a process of stabilization that memory researchers call *consolidation*. The term itself suggests that memories become solidified and strengthened once stored. Nevertheless, recent studies show that upon retrieval, information from a long-term memory enters a short-lived, labile state, when it is susceptible to changes, either in strength or in content. In this state a memory trace can go through various modifications, namely, it can be impaired, enhanced or distorted (Nader, 2010). This phenomenon has been given a name of *reconsolidation* and is considered to be a relevant integral part of long-term retention processing. The term itself may be misleading, because *reconsolidation* is not just a repetition of *consolidation.* Despite their similar function of storage and matching basic mechanisms, this post-retrieval stabilization differs from prior occurring *consolidation* and is responsible for the plasticity in old memories.

Two main hypotheses concerning the function of reconsolidation have been proposed. Some researchers ascribe for reconsolidation a role of memory strengthening and increasing its long-term persistence (Sara, 2000b; Inda, 2011). Parvez and collaborators (2006) demonstrated that when memory is reactivated through the re-experience of a stimulus, provided in the same context as former intermediate memory training, it promotes the long-lasting retention of the memory trace. Furthermore, Inda and colleagues (2011) have conducted an animal study with rats, in which multiple short retrievals of a young (one week old) memory traces provoke memory enhancement and prevent forgetting.

Another role is memory updating. It can be defined as all changes that are embodied into a reactivated memory trace as a result of ongoing perceptual input (Alberini, 2011). After retrieval, a few other learning processes usually co-occur (Tronson, 2007). For instance, the original memory trace might be enriched with emotional or sensory input or some contextual clues. Therefore, every time a mnemonic trace is retrieved it suffers changes because it is experienced in a different occasion along with different contextual information. Recent experimental neurobiological studies of reconsolidation emphasize that this process, dependent on a protein synthesis, happens exclusively in a combination with the integration of some new information. Tronson (2007) postulates also, that such new information introduced at reactivation of an old trace activates a "new encoding state" which is needed for reconsolidation. Its role in updating memories agrees with the capacity of their post-retrieval reinforcement.

Reconsolidation effects have been already shown for implicit forms of memory, procedural memory and conditioning (Hupbach, 2007). However, more recently, Hupbach (2007) demonstrated also that reconsolidation regards explicit memory (a mode in which an individual is capable to consciously recollect an event), namely - episodic memory. This research is very relevant for the hypothesis of reconsolidation as a mediator of memory updating. In his study, Hupbach (2007) used the list learning method. Participants were asked to remember a list of objects and after one-day delay were primed to recall those objects before learning another list. It was observed a significant number of intrusions from the second list on the first one at a later memory test. It means that subjects updated list 1 with some items from list 2. This finding directly shows a role of reconsolidation in updating memory.

Some opposite findings on reconsolidation occurrence after retrieval have brought researchers to a debate on its boundary conditions (Tronson, 2007). They indicate factors like the age of the memory, i.e. the time that has passed since training, memory strength, understood as the amount of training, and the duration of reactivation trial. These limiting conditions decide what happens with memories after a retrieval tentative - whether they undergo reconsolidation or are extinct. What is found is that new and strong memories are more prone to manipulations after retrieval and brief reactivation periods provide more probability for reconsolidation to take place. The availability of new information at retrieval may be a limiting factor as well. However, these conditions can also interact. For instance, a prolonged retrieval trial may lead to reconsolidation in older memory traces and very short reactivations may provoke an incomplete disruption of reconsolidation process and temporary deficits in memory.

Reconsolidation is a significant mechanism on the way to comprehend memory plasticity and has a potential to explain the process of incorporating new information into past experience. Although many studies have showed a disruptive force of retrieval, it has also been demonstrated (Hupbach et al., 2007) that reminders may also activate constructive mnemonic performance, which allows for the inclusion of new data into old memories. Reconsolidation account does not predict the direction of impact on memory. It only states that reactivation reopens existing memories for potential alteration. It is the post-reminder manipulation that in fact gives the direction of influence. Therefore, memory performance may be enhanced, weakened or some new information can be added.

The present study involves the manipulation of memories in the period after they have been recalled. Therefore, this section presented possible functions of reconsolidation – memory updating and strengthening - while discussing the role of the cognitive processes taking place immediately after the retrieval of a memory trace.

Correlation between arousal, mild stress, negative emotion and memory enhancement

People tend to remember well emotional events. It has been demonstrated in numerous experimental studies that emotionally arousing experiences are likely to be better remembered than neutral ones. As claimed by the modulation hypothesis (Sommer et al., 2008), arousal is the essential agent in the emotional enhancement of memory (EEM). This effect can be observed from encoding to retrieval search and acts of recollection (Buchanan, 2007). Although the EEM is more visible after longer retention intervals, the items that provoke arousal are often better remembered soon after encoding task too (Sommer et al., 2008). Sommer and collaborators (2008) found that arousal-based EEM happens even in the absence of memory enhancing cognitive characteristics of emotional stimuli, like their semantic relatedness and distinctiveness of items, which are supposed to attract more selective attention. The augmented activity of amygdaloid complex and hippocampus alone (structures responsible for emotional reactions and consolidation of information to long-term memory, respectively) are in agreement with the proposal that EEM is indeed arousal-driven. These two cerebral structures are matched to two independent memory systems and each of them plays particular roles. When an individual faces an emotional-arousing situation amygdala and hippocampus interact - the amygdala has the potential to modify both the encoding and the storage of hippocampal dependent memories. Hippocampus in turn, can influence the reaction of amygdala through creation of episodic representations of the emotional meaning of events (Phelps, 2004).

Both animal and human studies provide evidence that release of stress hormones (noradrenergic activation) leads to stimulation of amygdala and other regions important for sensory processing and cause arousal-driven memory enhancement (McGaugh, 2006). Adrenaline and cortisol, released due to emotional excitation, boost long-term retention after their application to rats during post-training experience. Results from human research confirm also that administration of adrenaline just after a learning episode or creating stressful experimental conditions, that provoke adrenaline eruption, strengthens memory. This enhancement occurs because noradrenergic activation of amygdala leads to modulation of memory processing in hippocampus. Pharmacological studies demonstrated that when stress hormones antagonists are applied and adrenaline effects do not occur, it hinders the memory enhancement caused by emotional incitement. Anderson and colleagues´ (2006) findings correspond to above mentioned results. In their study every emotionally neutral picture (test event) was followed by an unrelated image that varied in emotional intensity (modulator event). The results showed that processing of the latter strengthened memory for a former event but it was also noted, that the emotionally charged photos boosted memory of the prior presented ones only when their presentation did not surpass 4 seconds. Therefore, stress hormone activation of amygdala seems to play a crucial role for the short-latency modification caused by mild emotional incitement. However, researchers claim that it is direct neurobiological reaction on arousing stimulus and not focused attention or elaboration of an event that enhances the memory consolidation.

Cahill and McGaugh (1998) confirm the above account involving the amygdaloid complex (AC) in the arousal-driven enhancement of declarative memory (i.e. explicit memory of facts and knowledge). They give the example of patients with lesions in AC. A few investigations report that in these patients long-term memory, influenced by emotional events, is indeed impaired while the remembering of unemotional items remains intact. However, their emotional reactions to the emotionally charged stimuli seem to be normal. Taken these information together it may be concluded that amygdala complex in humans is not essential for emotional reaction itself but it is important for its translation into strengthened long-term recollection.

Sara´s (2009) animal study indicates that pharmacological or electrically stimulated release of noradrenaline is an efficient method of retrieval facilitation. An exposure to the experimental context (contextual cue reminder), if it is associated with reinforcement, also brings a similar result of facilitation. Another study with rats demonstrated that in the absence of an enzyme (dopamine beta-hydroxylase), which conditions the synthesis of noradrenaline, the animals, though they could learn a contextual-conditioning task, it turned out that they did not remember the experience 48 hours after training. When noradrenaline supply was given back the retrieval function was also restored.

According to Buchanan (2007), who draws from cognitive psychology studies, retrieval may be influenced either at the level of item, it means, the memory for an emotionally provocative stimulus, or at the task level, where a current mood of a participant during retrieval attempt is considered. Regarding emotion effect on items, it can modify two forms of their retrieval - familiarity and recollection. To evaluate the impact of emotion on these aspects of memory, Ochsner (2000) designed a study (using the *remember/know* procedure) to verify, if emotional events would be recollected and remembered more often than neutral ones. He discovered that presentation of arousing emotional scenes led to better recollection than neutral stimuli. What is more, this effect was more pronounced for negative and highly arousing images. Negative stimuli were also remembered more often than positive. Similar results were obtained for the presentation of emotional words instead of scenes (Kensinger & Corkin, 2003).

Kensinger (2007, 2009) report that arousal, induced particularly by a negative emotion, enhances memory for intrinsic features of an item but not of extrinsic details from context. Intrinsic attributes are the elements of an emotional event that have to be attended to process the affective relevance of the information. However, this distinction may refer not only to external details but also to individual´s thoughts and feelings elicited by the event.

Neuroimaging research suggests that valence may have a significant influence on retrieval processes. It turns out that there are some differences in processes employed at retrieval of positive and negative experiences at the neural level (Kensinger, 2009). According to these studies, positive events engage frontal brain regions associated with conceptual and semantic processing, while negative events elicit more rear sensory areas. To date, it is believed that interactions between emotion and sensory processing regions may be stronger at retrieval of negative experience compared to positive one.

Earlier studies demonstrated that retrieval is most successful if processes involved during encoding and retrieval correspond (Kensinger, 2009). Recently, data from neuroimaging research revealed a match between negative emotion and sensory processing both during memory encoding and retrieval. Hence, it makes sense that the way in which people remember information (i.e. perceptually or conceptually) would influence and guide memory retrieval and the type of information that would be retrieved.

This section was meant to call attention to the phenomenon of enhancing memory through inducement of negative emotional arousal. Particular attention was given to the role of stress hormones, which trigger activation within the amygdala. Amygdala activity in turn modulates memory processing in the hippocampus, where consolidation of information from short-term to long-term memory takes place. We ground our study on these findings looking for memory enhancement using negative-arousing emotional pictures.

First studies on memory enhancement through negative emotion arousal after retrieval

Lately, memory researchers conducted a few studies that embrace the issues of reconsolidation, negative emotion or mild stress driven arousal and long-term retention of information. Frenkel et al. (2005) reported that an enhancing effect of long-term memory occurred in crabs, when they were subjected to stressful condition (water shortage) upon reconsolidation phase. Coccoz and collaborators (2011) decided to transfer these findings to human ground. In order to assess if previously consolidated memory would be boosted at reconsolidation, they used a paradigm of human declarative memory - of pairs of cue-response syllables, which allows differentiating between a retrieved labile and non-labile state. On the other hand, to verify whether the memory trace can be modified by ongoing experience upon reconsolidation, they used cold pressor stress (CPS). The idea of Coccoz et al. (2011) study was to test whether human memory could be enhanced at reconsolidation phase by a naturalistic mild stressor. In the study, subjects were asked to learn an association between some cue-syllables and their corresponding response syllables. After a six-days delay, participants were presented with the reminder to reactivate the paired-associate memory. After that, during reconsolidation, they were stimulated with a mild stressor (rated by subjects as painful and unpleasant). On a subsequent memory test (7th day), participants who did not receive the CPS had poor memory performance. On the contrary, subjects administered with CPS, showed a robust mnemonic performance. Thus, Coccoz et al. (2011) findings reveal that a naturalistic mild stressor is capable to strengthen reconsolidation and improve the long-term declarative memory.

In the same year but independently, Finn and Roediger (2011) carried out the study with the hypothesis very much alike the Coccoz et al. (2011) one. This time it was presupposed that reconsolidation and long-term retention would be enhanced due to some emotionally arousing events that follow after retrieval. This presumption was set based on the knowledge that emotional centers of the brain, mainly the amygdala, have close interconnections with the hippocampus, an area employed during consolidation and reconsolidation. In the first experiment subjects had to learn Swahili-English translations and after that take a cued-recall test. When an English translation was successfully introduced, a blank screen, a neutral image or a negatively valenced arousing image was shown (with 500 ms duration). The results of this experiment revealed that arousal following successful retrieval of items improves their later recall. The novelty of these findings made researchers to conduct another experiment to replicate the effect. The procedure of the second test was exactly the same, only the start of the postretrieval event was delayed by 2 seconds. Obtained results showed that the effect persisted. Taking together, both experiments firmly established that a successful retrieval followed by a negative emotional arousal enhances indeed later recall. The third experiment of the study excluded the possibility of distinctiveness of emotional pictures as a source of memory enhancement.

A year later the same group of investigators decided to extend their study and designed two new experiments to find whether successful retrieval was a necessary condition to obtain the enhancing effect of negative emotion arousal on later recall (Finn, Roediger & Rosenzweig, 2012). In both experiments, the subjects learned once again Swahili-English translations and took a cued-recall test. In the first experiment, a distinctiveness explanation of the enhancing effect was verified. It turned out that neither presentation of a negative image before successful retrieval nor presentation of a positive picture after successful retrieval caused the enhancement, which was observed only in the condition where negative images were presented just after successful retrieval. This finding is in agreement with the reconsolidation assumption, that memory can be manipulated during a short time following retrieval. The aim of the second experiment was to check whether negative pictures enhancement would appear for unsuccessful, but active and effortful retrieval attempt, when a correct response was provided. Findings from several studies show that such a retrieval attempt, although unsuccessful, can involve the elaborative semantic processing. Also, the effort put into memory trace reactivation has been shown to determine if the reconsolidation and hence memory enhancement will occur. If retrieval is effortful enough to activate reconsolidation, the negative image presented after giving a correct feedback should provoke the picture´s strengthening effect on later recall. The study provided evidences that successful retrieval is unnecessary to produce the enhancing effect of negative emotion arousal on memory. What is critical is retrieval attempt and producing an initial answer.

The results of this research, as well as those of the previous ones (Coccoz et al., 2011, Finn & Roediger, 2011), reveal the plasticity of retrieved memories. They are in line with the extensive evidence that emotion, particularly negative emotion, influences the accuracy of memory (Kensinger, 2007). They also demonstrate that either retrieval or its active and effortful attempt is crucial for the emotional enhancement of the testing effect and support the account that reconsolidation contributes to the memory strengthening advantages of testing.

This section introduced and reviewed previous research including the first scientific outputs concerning memory enhancement via negative emotion arousal in the postretrieval period. The present investigation tries to replicate these initial results and extends them into the realm of false memories.

The present study

The present study combines the domain of false memories with the reconsolidation hypothesis and enhancement effect of negative emotion on long-term retention. The goal is to verify whether this kind of memory distortion is susceptible to the same enhancement effect Finn and Roediger (2011, 2012) reported for veridical memories, i.e. whether negative emotions, transmitted via images presented after recall (during reconsolidation), can facilitate remembering and enhance the retention of false memories, when they occur.

The first task of the study is based on the classic paradigm DRM in order to generate false memories. For this purpose, Portuguese DRM lists of associated words (Albuquerque, 2005) are used. The use of these wordlists permits to obtain an elevated degree of false memories, i.e. of non-presented critical items recall.

At the free recall task, every time a critical word was retrieved it was followed by a negative valence or neutral picture. Some target words (veridical memory) retrieved were also followed by a neutral or a negative picture following an odd-ball paradigm. The remaining successfully retrieved targets were followed by a blank screen. A bulk of studies proved that the memory performance is strengthened when an episode is accompanied by negative, as compared to positive or neutral events, hence we expect to obtain a reinforced retention of critical items (false memories).

A final test of free recall of all words of the lists is used to verify whether false memories that were followed on the first retrieval task by images transmitting negative emotions (facilitating conditions), were better remembered than those followed by either neutral images or blank screen.

In the end of the study a recognition test of images was made (composed of pictures which really appeared during the study and new ones). It served to complete the experiment and make it plausible for the participants.

In sum, in this study, it is expected to replicate the results of Finn and Roediger (2011, 2012), confirming the increase of veridical memories via postretrieval processing and influence of negative emotions. More importantly, in the present study the phenomenon of false memories will be submitted to the same test.

Method

Participants

A group of 146 students took part in the study. They were all undergraduates of University of Lisbon from the Faculty of Psychology. They participated in the experiment for course credit. Eight of them were excluded from all of the analyses that follow for failing to answer most of the items correctly on either the initial or the final test, leaving the data for 138 participants. 114 of them were women and 24 were men. The average age of participants was 21.

Design

For this experiment it was used a 2 order of feedback following retrieval of critical items (negative-neutral, neutral-negative condition) x 2 retrieval condition (initial retrieval, final retrieval) x 3 picture event type (blank screen, neutral picture or negative picture) design. With the first factor between subjects (79 participants in the negative-neutral condition and 59 in the neutral-negative condition) and the second and third factors manipulated within subjects. Dependent measures were the proportion of, false and veridical memories.

Materials

The study material for the free recall task was composed of 8 DRM lists (see Appendix A). They were taken from the study of Albuquerque (2005) and chosen according to the highest rate of false memories they generate (more than 40%). However, only 8 from 15 associated words of each list were presented to participants.

The lists were modified in such a way that the second item of each list was taken as a second critical word. In the negative-neutral condition the first, nominal critical item (IC1) was supposed to be followed by a negative picture and the second critical item (IC2) by a neutral one. In the neutral-negative condition the situation was contrary - IC1 was succeeded by neutral and IC2 by negative one. The lists were presented to each subject at random order and it was generated by E-prime.

The pictures stimuli (see Appendix D) that were presented after the retrieval attempt were taken from the *International Affective Picture System* (IAPS; Lang, Bradley & Cuthbert, 2008). The system is based on a 9-point rating scale in which higher values correspond to more positive values when the pictures are evaluated on valence or arousal. The negative images that were used here (e.g., dead people or pointed gun) had an average valence of 2,22 (range from 2,83 to 1,67) and an average arousal of 5,74 (range from 6,86 to 4,31). The mean valence of neutral pictures (e.g., landscape or a teaspoon) chosen to the experiment is equal to 5,79 and the mean arousal is of 3,14.

Procedure

Participants were told at the beginning that they will take part in the study about memory and emotion. The experience started with participants reading the instructions presented on the computer screen (see Appendix C).

They had been given information that they will see 8 lists of Portuguese words to study. Then, they had to recall the list words after the presentation of each list. After every single recollection an image or blank screen was presented to them. In the end of the experience they were asked to perform the same recall task but with all of the words that had been given before. The participants were also warned to pay attention to occurring meanwhile pictures due to the final image recognition test.

Subjects were presented with a list of 8 Portuguese words to memorize. The words appeared on the computer screen one after another and the presentation of each word lasted 4 seconds. After that, they performed during 1 minute a distractive task (multiplication task, finding details in a picture or optic illusion with additional counting task; see Appendix B) to impede the retention of learned words in short memory. Then, they were asked to recall the previous list of words. Participants typed in their answers and hit Enter button after each answer (recalled word). They had unlimited time to introduce the response and were not forced to give it. They were asked not to guess. This procedure was repeated 8 times, one for each list.

Participants in the negative-neutral postretrieval condition, that happened to evoke an IC1, a negative picture was presented immediately after that false recall. In the case of IC2 recollection, a neutral picture occurred.

In contrast, in the neutral-negative postretrieval condition, if subject typed in an IC1, a neutral image was presented and if an IC2 was typed in, it was followed by negative picture.

The condition with blank screen was used only for veridical memories (targets) and not for false memories.

Blank screen or neutral picture succeeded incorrectly introduced (erroneously written or intrusions) items.

Images (negative, neutral, blank screen) were presented for 1,5 second. The presentation order of the pictures was random over all 8 lists.

In the case of veridical memories, a negative picture was presented at most once per 8-item list, according to the oddball paradigm (an experimental method in which a target stimulus is presented amongst more frequent standard background stimuli).

After the initial free recall phase, when all 8 lists had been studied and tested, participants were given a final recall task. They were asked to retrieve and type as many words from all the lists as they could. The participants had for this task as much time as they needed.

In the end of the experience subjects took a final test on picture recognition. The test included some of the images that really had occurred over the initial test phase and new ones. The participants had to press button "1" to confirm or button "2" to deny the occurrence of the given image. The order of pictures was randomized.

In the end subjects were thanked for their participation in the study.

Analysis of results and discussion

Our interest lies primarily in the effect of remembering of critical and veridical words in the initial and final retrieval condition as function of picture valence (neutral and negative)[3]. We thus examined the interaction between these two variables.

Analysis of false memories

The second critical item (IC2), picked additionally from DRM lists, turned out to be impossible to analyze. It was hardly ever recollected (only 4 single cases of recollection in initial task and no recollection in final task). Consequently, it was eliminated from further analysis. Hence, a comparison between retrieved critical items (false memories) followed by neutral or negative images was only possible between participants.

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[3] While for veridical memories (targets) all three picture types (negative, neutral and blank screen) are subjected to analysis, when comparing veridical to false memories, we only examine negative and neutral condition. Blank screen condition for targets was used due to the use of the oddball technique. Blank screen and neutral images played the role of control conditions. Following the studies of Finn & Roediger (2011, 2012) we employed both of them. Although previous research (Anderson, 2006) demonstrated differences in salience between these picture events (contributing for distinctiveness factor), in Finn & Roediger (2011, 2012) studies performance for items in neutral and blank condition did not differ significantly.

A repeated measures ANOVA with retrieval condition (initial vs. final) as a within-participants factor and picture type (negative vs. neutral) as a between-participants factor was carried out with proportion of false memories (critical items retrieved) as the dependent measure. There was a significant main effect of retrieval condition, F (1,136) = 107.39, MSE = .52, p = 0.017, $\eta\rho^2$ = .44, indicating a better retrieval for critical items in initial (M = .223, SE = .017) than in final retrieval task (M = .109, SE = .011).

This result is in agreement with the well-known forgetting curve, as it shows the decline of memory retention with the passage of time. A typical forgetting curve suggests that humans tend to maintain approximately half of their memory of newly learned knowledge in a matter of very short period of time if they do not consciously remember the learned information.

The main effect of picture event type (negative vs. neutral) was marginally significant, F (1,136) = 3.43, MSE = 3.04, p = 0.066, $\eta\rho^2$ = .025. False memories followed by negative picture (M = .142, SE = .017) were less frequent than false memories followed by neutral picture (M = .191, SE = .020). We have no explanation for this difference.

Finally, the interaction between the two conditions was significant F (1,136) = 5.82, MSE = .52, p = 0.017, $\eta\rho^2$ = .04, indicating, as expected, a greater decline of false memories followed by neutral than by negative pictures (see Figure 1).

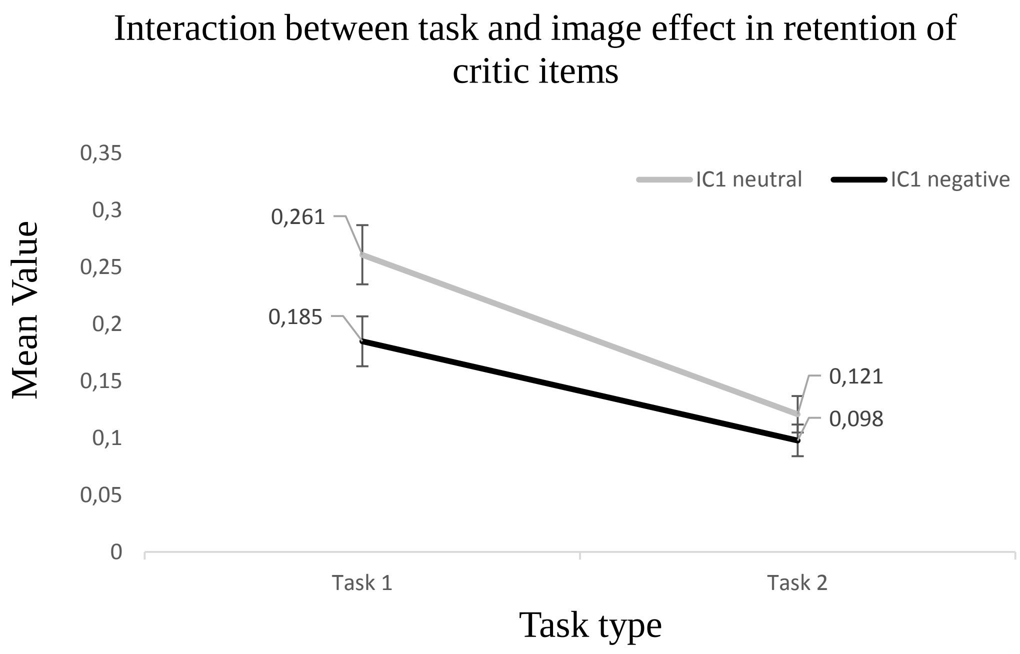

Figure 1. Mean values of interaction between task type (initial vs. final) and image type (neutral vs. negative) in retention of IC1. Standard errors are represented in the figure by the error bars attached to each line.

As aforementioned, for some unknown reason, the number of false memories in the first retrieval moment was greater when they were followed by neutral image as compared to when they were followed by negative image. To nullify this initial difference we reanalyzed the data dividing the proportion of final false memories by the proportion of initial false memories, followed by neutral or negative pictures.

An independent-samples *t*-test was conducted to compare the computed proportions. There was no significant difference in the scores for false memories followed by negative (M = .498, SE = .054) and by neutral picture (M = .477, SE = .050); t = -.275, p = 0.784. These results indicate that when controlling for the initial discrepancy between the rate of false memories followed by negative versus neutral pictures, picture type does not have the expected consolidation effect on false memories. Although the means have the predicted direction and we can observe better consolidation for false memories succeeded by negative than by neutral pictures, the obtained effect is not significant.

Analysis of veridical memories

The analysis regarding veridical memories became considerably limited because we obtained only a small number (41 in initial and 4 in final task) of targets that were followed by negative images due to the use of the oddball paradigm. This lack of correct answers led us to analyze the data per list and not per participant.

An ANOVA with picture type (negative vs. neutral vs. blank) as a between-participants factor was computed with proportion of veridical memories (targets retrieved) as the dependent measure. No significant difference in retrieval was found between targets followed by negative picture ($M = .57$, $SD = .13$), neutral picture ($M = .56$, $SD = .09$) or blank screen ($M = .56$, $SD = .10$); $F\ (2,6) = .027$, $p = 0.973$, *Wilk´s* $\alpha = .99$. Thus, our veridical memories results do not replicate here the output obtained by Finn and Roediger (2011, 2012).

To maximize the possibility of detecting an effect of picture type we aggregated the results from the analysis per list and per participant (see Table 1).

Table 1

Mean Value of Targets Followed by a Picture Event (Negative, Neutral or Blank) in Initial and Final Task Summed up from the Analysis per List and per Participant

	Mean	Std. Deviation
Initial Task		
Targets (NEG)	,9493	3,52
Targets (NEU)	23,15	4,56
Targets (BLANK)	23,84	4,51
Final Task		
Targets (NEG)	,38	,64
Targets (NEU)	13,50	5,22
Targets (BLANK)	14,28	5,28

We then divided the proportion of final retrieval of targets by initial retrieval of targets for each variable level (negative, neutral or blank). We obtained the following values: 0.4 for targets followed by negative pictures, 0.58 for targets followed by neutral pictures and 0.59 for targets followed by blank screen.

A *t*-test for dependent proportions, comparing the proportions of veridical memories succeeded by negative pictures and by neutral pictures and blanks taken together (with a mean proportion of 0.585) showed a significant difference, $t(137) = 3{,}18$, $p < 0.001$. The remaining comparison between veridical memories followed by neutral pictures and blanks was not significant, $t < 1$. These results provide some evidence in agreement with the hypothesis that negative pictures cause a smaller decline in veridical memories forgetting.

The final analysis of memory test on picture recognition was not carried out as in Finn and Roediger (2011, 2012) studies. As mentioned above, this test served to complete the experiment and make it plausible for the participants. It could not have influenced the main results above described.

General discussion

In their pioneer studies Finn and Roediger (2011, 2012) provided the first evidence that veridical memories can be enhanced via postretrieval negative emotion. Those results are also in favor of the testing effect, given that they have shown that processes underlying this effect are not limited to the retrieval period but also embrace a period of reconsolidation following either successful or unsuccessful but effortful retrieval.

In the present study, which followed Finn and Roediger´s (2011, 2012), our goal was to extend their hypothesis and examine whether false memories would be enhanced by the postretrieval negative emotion arousing manipulation. We achieved this goal by presenting negatively charged emotional images in the period immediately following items recollection, i.e. at memory reconsolidation, and verify if this procedure would facilitate later retrieval and enhance long-term remembering of false memories.

Using DRM lists we expected to replicate the results from Finn and Roediger (2011, 2012) concerning veridical memories and to show a similar effect for false memories.

The obtained results did not reveal any significant improvement in retention of false memories followed by negative images. Nevertheless, an outstanding observation is that nominal critical items (IC1) from the first condition had a forgetting curve (Ebbinghaus, 1999) less inclined as compared to those followed by neutral images. It means, critical items matched to negative pictures suffered less memory decline of (less forgetting effect) than critical items linked to neutral pictures. Thus, this study did not clearly show the enhancing influence of negative emotions but we demonstrated that arousal provoked by negative images is able to limit and decelerate the process of forgetting.

Regarding task type, better recollection of critic items in initial than in final task was noticed. It is typically due to memory transience, it means to forgetting, which occurs with the passage of time.

In what refers to veridical memories, the results provided some evidence in agreement with the hypothesis that negative pictures, comparing to neutral ones or blank screen, cause memory enhancement. Following Finn and Roediger (2011, 2012) findings, we can state that veridical memories, which were succeeded by negative images, underwent reconsolidation and benefited from arousing picture manipulation. Our results for veridical memories are then consistent with the extensive evidence that emotions influence the accuracy of memory.

An important limitation of the present study stems from the use of the oddball paradigm. Its primary function was to ensure the distinctiveness of image factor (negative picture) by making it a task-relevant item and so it could stand out with respect to its context – more frequent stimuli (in the present case: neutral pictures or blank screen). The paradigm was supposed to guarantee that a negative image would appear rarely. However, it turned out that it drastically reduced the number of negative pictures at recollection of veridical items and thus, turned their analysis asymmetric and impossible to be done by participant. We gathered an insufficient amount of targets followed by negative pictures, which hindered the analysis of data.

Another limitation of the experiment was the dependence on participants´ false memories generation. Some of them did not retrieve any critical item. In particular, the second critical item (IC2), was hardly ever recalled. Therefore, it became impossible to carry out the comparison of two conditions of the study, negative-neutral (with IC1 followed by negative and IC2 by neutral images or blanks) and neutral-negative (with the opposite images matching).

The pictures selected to the experiment may also be considered a limiting factor. That is because the effect of arousal, the images are supposed to create, depends in fact on participants' subjective sense of negative feelings they provoke. Although the pictures were all taken from the resources of *International Affective Picture System* (IAPS) and chosen to have possibly the lowest valence (the biggest negative emotional charge) and relatively high degree of arousal, the perception of negative message was subjective in each participant and the arousal it elicited was not assessed. To address this issue, future studies could obtain behavioral and physiological measures of arousal when participants see the emotional images.

A proposal for future studies is to clarify whether the memory enhancing effect is dependent on the use of the oddball paradigm or a more balanced design (with the number of images more equated per block) would obtain the same results. In our study we decided to follow Finn and Roediger´s experimental design based on the oddball technique which ensured the distinctiveness of the negative pictures and was expected to substantially increase the immediate emotional enhancement of memory (EEM) (Schmidt & Saari, 2007; Talmi et al., 2007). However, this technique strongly restricted the global output, which hindered data analysis. Although previous neuroimaging studies could not separate the contribution of arousal and cognitive factors like distinctiveness to the EEM, Sommer et al. (2008) provided evidence that this enhancement is exclusively arousal-driven. In their fMRI study they eliminated the impact of cognitive factors to the EEM at encoding so that results they obtained are an important proof for the modulation hypothesis, which proposes that interaction between amygdala activity and memory encoding is driven by the arousal of stimuli that triggers the amygdala. The authors of the study suggest that neither distinctiveness of arousing stimuli nor the differential attraction of selective attention contributed to the differences in encoding efficiency. They concluded that the more an item was momentarily perceived as arousing, the more its processing was accompanied by increased amygdala activity the more efficiently it was encoded. The study of Sommer et al. (2008) provides a strong evidence that EEM is in fact a reflection of differences in experienced arousal and not of cognitive factors. Therefore, it is proposed that future studies could avoid the use of the oddball paradigm and rely on more balanced design and use of greater number of negative stimuli.

Although our results do not present robust evidence that negative emotions enhance false memories, the obtained decrease in forgetting effect at retrieval after negative emotion manipulation signals that this phenomenon needs further studying.

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APPENDICES

Appendix A

Lists of presented words

Table 1

Presented DRM lists

Frio	**Lento**	**Doce**	**Agulha**	**Música**	**Vinho**	**Beijo**	**Fome***
Inverno	*Rápido*	*Bolo*	*Picada*	*Som*	*Tinto*	*Amor*	*Comida***
Neve	Tartaruga	Agradável	Dor	Dança	Bebida	Carinho	Miséria
Casaco	Vagaroso	Salgado	Costura	Relaxamento	Garrafa	Lábios	Pão
Lareira	Preguiçoso	Açúcar	Alfinete	Cantar	Verde	Namorado	Sede
Roupa	Demorado	Mel	Linha	Calma	Álcool	Paixão	Pobreza
Calor	Moroso	Chocolate	Dedal	Ouvir	Jantar	Bom	Guerra
Quente	Caracol	Algodão	Palheiro	Notas	Uvas	Carícia	Tristeza
Gelo	Devagar	Amargo	Fina	Rádio	Água	Ternura	Mal
Manta	Tempo	Guloso	Coser	Alegria	Copo	Boca	Desespero

Note. ***** IC1 – 1st non-presented critical item (bold-faced) ** IC2 – 2nd non-presented critical item (italicized)

Appendix B

Distractive tasks

1.

2. Quantas caras consegue ver nesta imagem? 9, 11 ou 13? Escreva a resposta utilizando as teclas numéricas e pressione "ENTER" para confirmar.

3. Por favor olhe atentamente para a imagem durante 20 segundos. Quantas caras é possível ver nesta imagem? Seleccione a sua reposta utilizando o teclado.

Tecla "1": uma cara.

Tecla "2": duas caras.

Tecla "3": três caras.

4. Na tarefa seguinte pedimos-lhe para resolver várias contas de multiplicação. Introduza o resultado utilizando as teclas numéricas do teclado. Caso se engane, poderá corrigir até 3 caracteres da sua resposta utilizando a tecla "BACKSPACE". Confirme a sua resposta com "ENTER". Pressione "ESPAÇO" para começar. – The task repeated 4 times.

Appendix C

Instructions

1. *Seja bem-vindo ao estudo! Ser-lhe-ão apresentadas 8 listas de 8 para estudar. Depois de cada lista realizará uma tarefa de rocordação das palavras apresentadas. Logo após escrever cada palavra recordada aparecerá uma imagem ou um ecrã em branco. Deve prestar atenção às imagens, no final haverá um teste de reconhecimento das imagens. No final da experiência realizará uma tarefa de recordação onde terá de escrever o máximo de palavras de todas as listas de que se conseguir lembrar. Pressione "ESPAÇO" para continuar.*

2. *A apresentação das 8 listas irá começar de seguida. Cada lista é composta por 8 palavras. Cada palavra é apresentada durante 4 segundos. No final da apresentação de cada lista irá resolver uma tarefa de recordação onde terá de escrever todas as palavras da lista de que se lembrar. Pressione "ESPAÇO" quando estiver preparado para começar.*

3. *Ser-lhe-á apresentada uma lista de 8 palavras. As palavras da lista têm um tema comum. Leia a lista atentamente e tente memorizá-la. Pressione "ESPAÇO"para começar.*

4. *Tente lembrar-se das palavras que foram apresentadas e escreva-as utilizando o teclado. Não precisa de as escrever pela ordem em que apareceram. Quando não se lemrar de mais palavras, não escreva nada e pressione "ENTER" para terminar. NÃO SE ESQUEÇA! Deve prestar atençã às imagens. ATENÇÃO! Por favor escreva as palavras SEM caracteres especiais (ex.: use "C" em vez de "Ç") e sem acentos*

(~´`^). Caso contrário as suas respostas não serão registadas pelo computador. Pressione "ESPAÇO"para começar.

5. *Atenção! Não insira todas as palavras de uma só vez. Por cada palavra de que se lembrar, escreva-a e pressione "ENTER" para a confirmar e passar para seguinte. Quando não se lembrar de mais palavras simplesmente deixe em branco e pressione "ENTER" para terminar.*

6. *Quando não se lembrar de mais palavras, deixe a caixa em branco e pressione "ENTER" para terminar. Prima "ESPAÇO" para iniciar a caixa onde irá inserir as palavras.*

7. *De seguida ser-lhe-ão apresentadas várias imagens. Durante a tarefa terá de indicar se a imagem já lhe foi apresentada anteriormente ou não, utilizando as teclas numéricas "1" e "2". Tecla "1" – reconhece a imagem, tecla "2" – não reconhece a imagem. Pressione "ESPAÇO"para começar.*

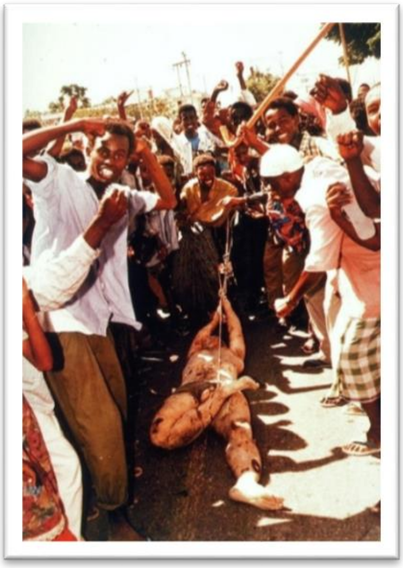
Appendix D

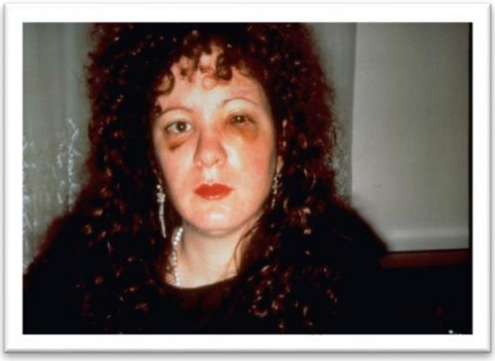
Images from International Affective Picture System (IAPS)

1. *Negative images (presented and non-presented in the study)*

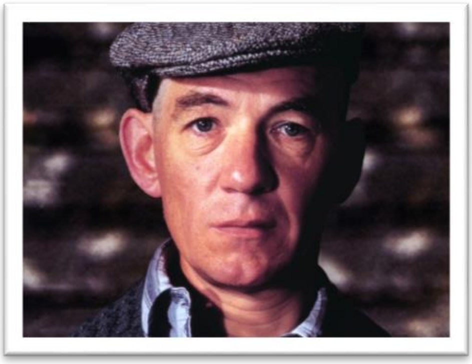




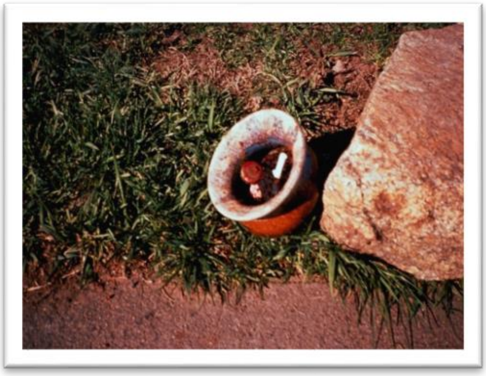


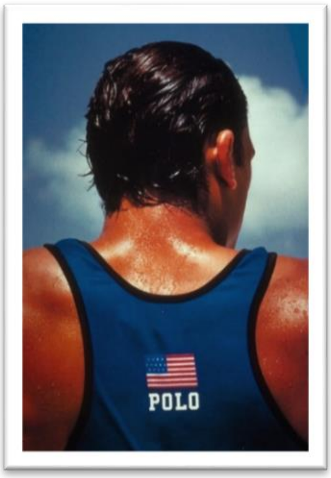



2. *Neutral images (presented and non-presented in the study)*

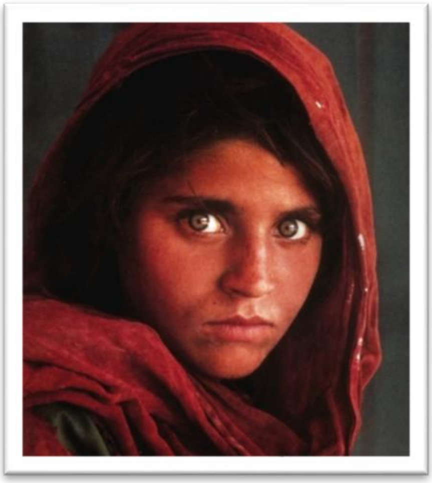





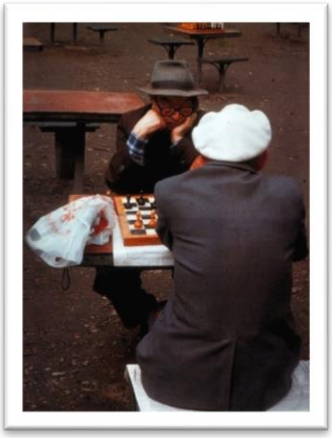


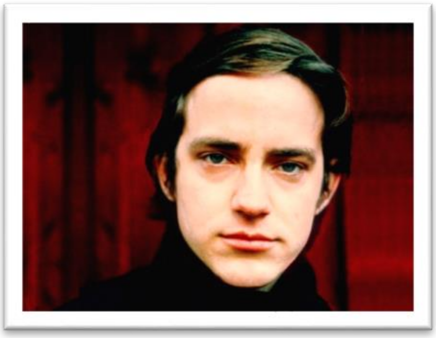

POLO







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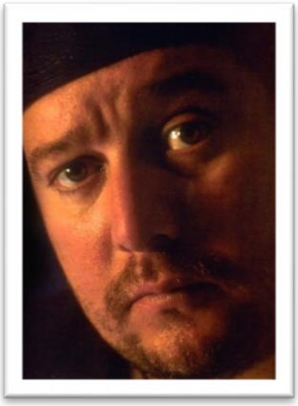
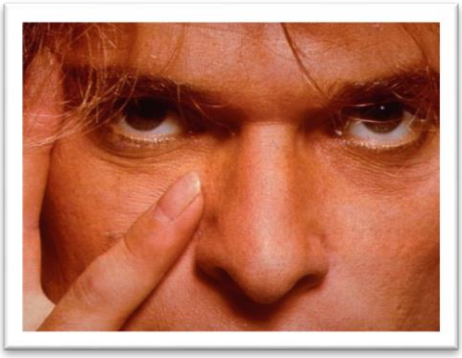
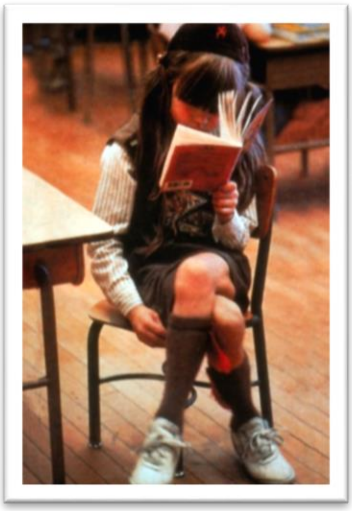
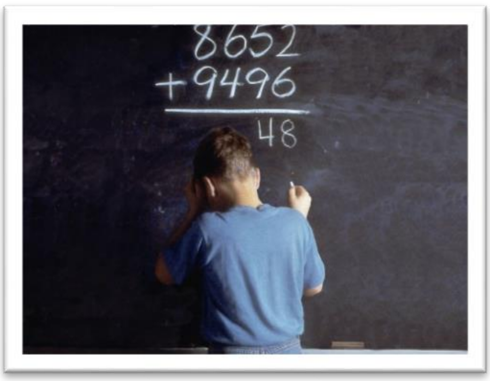
1
2
IGHT HAND





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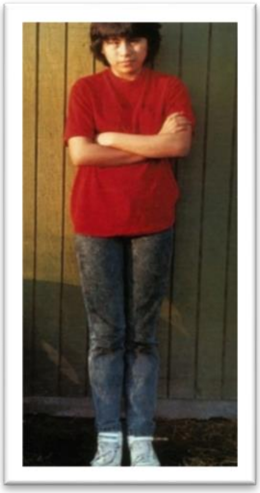
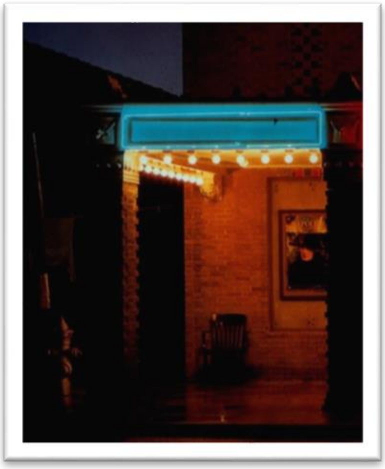
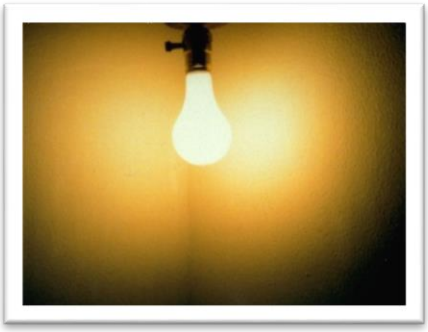
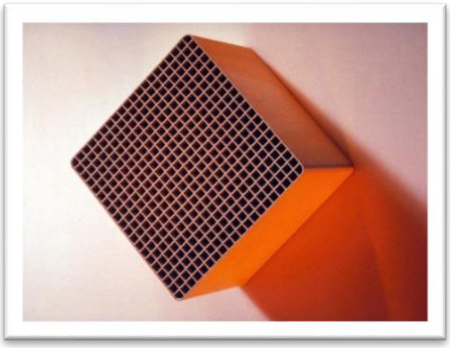
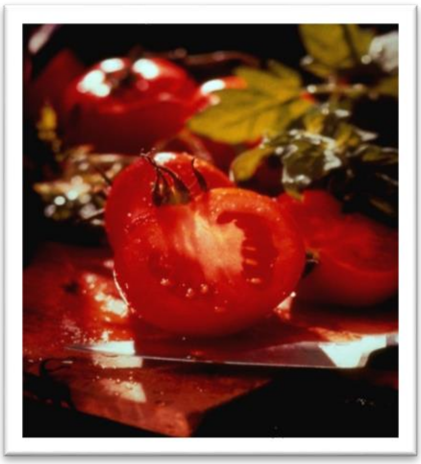
48









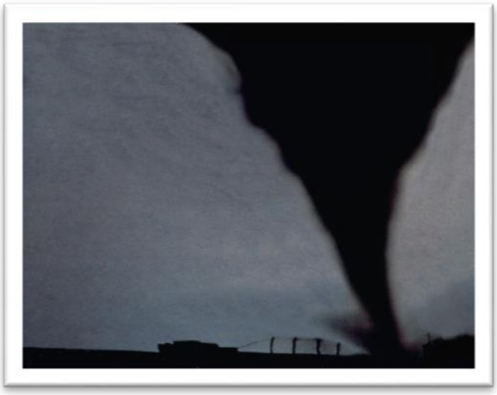















McDonald's